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CASE STUDY

Assessing the environmental profile of orange production in Brazil

Leda Coltro · Anna Lúcia Mourad · Rojane M. Kletecke · Taíssa A. Mendonça · Sílvia P. M. Germer

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Abstract

Background, aim, and scope Brazil is the world's largest orange producing country, with a total planted area of more than 820,000 hectares. The bulk of the oranges produced in Brazil (70%) is processed into frozen concentrated orange juice (FCOJ) by large processing companies. Exports represent around 97% of the total FCOJ produced, making Brazil the largest world producer and exporter of FCOJ. The Brazilian citrus sector accounts for half of the world's supply of orange juice and for 80% of the juice traded on the international market. The goal of this study is to characterize the Brazilian orange producers in terms of farm size, cultivated varieties, watering system and tillage practices. In addition, the study presents some aspects of the LCI of oranges grown specifically for the production of FCOJ in the two major orange-growing areas in Brazil (the Northern and Southern regions of the State of São Paulo) during reference crop year 2002/03 in order to generate detailed production inventory data and identify the potential environmental impacts of tillage, both of which are key to enable the formulation of sustainability parameters for the production of FCOJ in Brazil.

Methods This study was performed in compliance with the guidelines and requirements of the ISO 14040 standard series. All information and data considered and evaluated in this study (the use of water, energy, fertilizers, pesticides and soil correctors) were gathered through in-depth questionnaires either filled in directly by the farm manager or completed by the farm manager and sent in by mail. The data cover a total of 367,200 metric tons of oranges produced by 4 million plants in commercial production from a total evaluated area that accounts for 19.5% of the overall production of oranges in the State of São Paulo. The two major orange-producing areas in Brazil located respectively in the Northern and Southern regions of the State of São Paulo were evaluated. Only the inputs and outputs associated with tillage practices and technology were considered in this paper. The environmental aspects of the production of fertilizers and pesticides were not included within the boundaries. The functional unit selected for this study was 1,000 kg of oranges for FCOJ. Farm-specific data have been combined with agricultural production data to construct an orange cultivation model.

Results The orange varieties for the production of FCOJ evaluated in this study were Pêra, Valência and Natal. The farms investigated had a cultivated area varying from 22 to 7,000 ha, with a plant density ranging from 170 to 500 plants/ha and an average yield of 30,500 kg/ha for mature trees. Depending on the region, the production of 1,000 kg of oranges requires approx. 120 to 4,400 MJ of energy; 0.3 to 36 kg of diesel; 1,100 to 54,500 kg of water for irrigation; 0.3 to 65 kg of fertilizers (NPK); 0.1 to 13.5 kg of pesticides; 8 to 650 kg of soil correctors. The distribution of some inputs across the farms located in the two main Brazilian orange-producing regions is presented, in addition to the total weighted average.

Discussion In addition to the variations among the regions evaluated, it was generally observed that there were very considerable differences in order of magnitude between the data collected from farms located in the same region. Although the inputs are directly related to the specific characteristics of each farm and the climatic and topographic conditions of its location, this study has identified some farms that are in a good position to reduce the

L. Coltro (✉) · A. L. Mourad · R. M. Kletecke · T. A. Mendonça · S. P. M. Germer
CETEA—Packaging Technology Center,
ITAL—Institute of Food Technology,
P.O. Box 139, 13070-178 Campinas, SP, Brazil
e-mail: ledacolt@ital.sp.gov.br

amounts of some inputs and enhance their environmental and economical performance.

Conclusions Taking into account the aspects evaluated in this study, only 21% of the orange growers showed good performance, i.e., consumption of pesticides, fertilizers and soil correction compounds equal to or lower than the weighted averages, except for “land use”, which was above the average for the majority of these farms. This study provided important results that allow for a better understanding of the agricultural practices involved and the potential environmental impacts of this product.

Recommendation and perspective The authors would like to suggest that the five best-performing farms average values be set as the maximum allowable level and point of departure for the discussion on the good environmental performance of Brazilian FCOJ. Besides the total inputs, the role of good agricultural practices to achieve good yields and, at the same time, improve the sustainability of orange growing should also be taken into consideration. Future updates of this study will show the evolution of natural resource management as a result of improved land use, new agricultural practices, reduced use of fertilizers and agrochemicals.

Keywords Agricultural practices · Brazil · Frozen concentrated orange juice (FCOJ) · LCI · Orange · Sustainability

1 Introduction

Brazil is the world’s largest orange producer, with a planted area of over 820,000 hectares. About 70% of the total orange production is delivered to frozen concentrated orange juice (FCOJ) processors. Exports represent around 97% of the total FCOJ produced, making Brazil the largest world producer and exporter of FCOJ. The Brazilian citrus sector accounts for half of the world’s supply of orange juice and for 80% of the juice traded on the international market (Garcia 2000).

During the 2002/2003 crop year, Brazil exported 1,284 thousand metric tons of FCOJ, corresponding to a more than 60% increase in the volume exported in 12 years. Agricultural production increased by 37% over the same period, totaling more than 360 million boxes (40.8 kg each) of oranges in the same crop year in the State of São Paulo alone, the main orange-growing region in Brazil (77%) (Abecitrus 2004).

The FCOJ production and export sectors comprise 11 processing industries and 29 thousand farms located in the São Paulo State, which employ 400 thousand workers and generate another 3 million indirect jobs (Embrapa/IAC 2000).

Citriculture is the primary economic activity in 331 cities located in the State of São Paulo, in addition to another 15 towns in the neighboring State of Minas Gerais, and yields 1.5 billion dollars annually. This sector employs the newest technologies and operates excellent transportation and distribution systems (Embrapa/IAC 2000).

1.1 Tillage

The production of oranges in the State of São Paulo is concentrated in three regions with different edaphoclimatic characteristics: the Northern, Central and Southern portions of the State. The Northern and Central regions are pioneers both in the production of oranges and FCOJ processing. However, in addition to facing phytosanitary problems (diseases and pests) that have not affected the Southern region so far, the Northern and Central parts of the state have non-optimal rainfall regimes for citriculture, according to the agricultural zoning plan drafted by the Institute of Agronomy of Campinas—IAC (Zoneamento Agricola do Estado de São Paulo 1974). That is the reason why citriculture is increasing in the Southern region, changing the map of the orange-growing areas in the State. In addition to continuously expanding the planted area, the citrus farmers in this region use more advanced technologies. For that reason, this study focuses on two orange-growing regions: the Northern and Southern portions of the State of São Paulo. The methodology developed for the purpose of this study took into consideration the edaphoclimatic characteristics and phytosanitary problems of these regions (Guilardi et al. 2002).

1.2 Climate and soil

Climate and soil are responsible for the different tillage practices in the growing of oranges. In each of the three São Paulo regions (North, Central-West and South) a diverse tillage practice prevails, for instance, since the North region has a lower incidence of pests and diseases and, consequently, requires the use of smaller amounts of pesticides as compared to the Mid-West region, where the incidence of pests and diseases is much higher. On the other hand, the soils in the North are different from those in the Mid-West, which also results in distinct tillage practices and systems.

Citrus trees adapt well to almost all kinds of soil due to the several graft carriers that can be used, allowing one to choose the most suitable for each condition. However, the topography should be flat or gently sloping. It is possible to plant citrus trees on terrains with a slope of up to 18%, provided that adequate maintenance practices are adopted.

The ideal annual rainfall index for soils for citrus ranges from 1,000 to 1,300 mm. The best temperature for

vegetative development is 23–32°C. Below 13°C and above 39°C there is no vegetative activity (De Negri 1997).

1.3 Varieties

Selection of the most appropriate variety is an important issue since tillage is perennial and depends on the location and the purpose for which the fruit is intended.

Depending on the purpose for which the fruit will be used, the following varieties can be planted with success in the areas specified: 1) for the domestic market: Lima, Baía (precocious); Pêra (mid-season); Natal and Valência (late); 2) for export: Baianinha (precocious); Pêra (mid-season); Valência (late); 3) for the processing industry: Piralima, Lima, Baianinha, Hamlin (precocious); Pêra, Westin (mid-season); Natal and Valência (late) (Pizetta 1999, Mattos et al. 1998).

The Pêra variety is preferred by the processing industry due to the quality of its juice. The Valência and Natal varieties are more resistant to transportation and their juice is of excellent quality. The Lima, Hamlin and Piralima varieties are susceptible to transport damage and their juice is of a lower quality than that of the above-mentioned varieties and, for that reason, it is usually blended into the FCOJ for export (Pizetta 1999).

The yields depend on the variety and are usually low (approx. 2 boxes / plant / year, i.e., 20,000 to 25,000 kg of fruits / hectare / year). According to Pizetta (1999), since one box of orange (40.8 kg) contains from 200 to 300 fruits, depending on the variety, a yield rate of 20,000 to 25,000 kg of fruits should be considered as low. This can be explained by the following factors: 1) excessively wide spacing, 2) inadequate tillage practices (weeding, irrigation, etc.), 3) absence of integrated pest management and phytosanitary practices, 4) inadequate application of fertilizers and soil acidity correctors. Well-managed and more tightly spaced orchards can produce over 40,000 kg of fruits / hectare / year (Pizetta 1999).

Today, the varieties grown in the State of São Paulo are almost exclusively those intended for the FCOJ industry, such as the Pêra orange. As a result, the sweet orange varieties (*Citrus sinensis Osbeck*) account for 80% of the Brazilian production (Números da citricultura paulista 2003).

1.4 Fertilizers

In order to grow and produce well, citrus plants need the following elements: carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, copper, boron, manganese, chorine and iron, which the plants draw from water, the air and the soil. Thus, soil analysis is an important tool that allows one to evaluate the fertility conditions and define what elements and how much of each should be provided to the soil through fertilizers (A cultura dos citros 2003).

Organic fertilizers supply nutrients to the plants and also improve the water holding capacity of the soil. The most used chemical fertilizers include: urea, ammonium sulphate, diammonium phosphate, monoammonium phosphate, simple and triple superphosphates, potassium chloride and sulphate (A cultura dos citros 2003).

1.5 Diseases and pests

Tillage is extremely important in citrus growing, given the countless pests and diseases that can cause irreversible damage to the trees if they find suitable conditions for their development. The quality of the fruits and the quantities produced are under a constant threat of damage from pests and diseases that can seriously affect or totally eliminate their fruit-bearing capacity and eventually lead to eradication of entire orchards. Thus, pest and disease control is fundamental for the survival of the orchard (SGC n.d.).

Among the many diseases and pests that attack citrus, special mention should be made of: citrus variegated chlorosis (CVC), citrus canker, citrus sudden death (CSD), black spot, leprosis, citrus leaf miner, citrus greening disease, *Ecdytolopha aurantiana,* citrus coccid *Orthezia praelonga,* etc. (Principais doenças e pragas 2006).

In Brazil, the pests and diseases that attack citrus must be controlled in accordance with the rules and practices recommended by Fundecitrus (Foundation for Citrus Plant Protection) for each individual pest and disease, employing active ingredients that are authorized for use in citrus integrated production, a program of the Brazilian Agriculture, Animal and Supply Ministry that establishes good agricultural practices (Principais doenças e pragas 2006). The recommended chemicals are applied by spraying.

2 Methods

2.1 General considerations

This study was conducted in accordance with the guidelines and requirements set forth in International Standard ISO 14040 (2006)—Environmental Management—Life Cycle Assessment—Principles and Framework .

Data storage and modeling were performed by means of the PIRA Environmental Management System—PEMS4 software purchased from Pira International.

Table 1 Crop characteristics of the evaluated orange farms

Parameters	Unit	Average	Minimum	Maximum	SD
Plants in production	Number of plants	189,068	4,500	1,630,000	412,551
Plant density	Plants/ha	342	167	509	88
Yields	kg/ha	30,576	14,209	54,528	10,726
Orange grove size	ha	691	22	7,000	1,596
Rainfall index	mm/year	1,359	1,194	1,496	89

SD = standard deviation

2.2 Goal and scope definition

The goal of this paper was to develop an LCI study—cradle-to-gate (economic flows)—of oranges for FCOJ produced in the major two orange-growing regions of Brazil (Northern and Southern regions of the State of São Paulo), as well as to contribute to the development and application of LCA methodology in Brazilian agriculture and help build a better understanding of how to reduce the environmental impacts and increase the sustainability of this product.

The scope of this work was to qualify and quantify the main environmental aspects of oranges for juice produced in Brazil in order to establish parameters for the sustainability of Brazilian FCOJ.

The Functional Unit used in this study is 1,000 kg of oranges for FCOJ. This functional unit bears no relation to the function of FCOJ, since the use stage was not included in the system. Thus, the cradle-to-gate approach was used as the basis for this LCI study.

2.3 System description

The system evaluated includes orange-growing on commercial farms, harvesting, storage and transport by trucks to the processing plants. This study evaluated the agricultural production of the varieties Pêra, Valência and Natal in the Northern and Southern regions of the State of São Paulo.

A wide range of crop characteristics was observed across the farms evaluated (Table 1). Plant density varied from 170 to 500 plants per hectare as a consequence of local topography, the plant spacings used, etc. Production systems with low (14,000 kg/ha) and high (55,000 kg/ha) yields were included in this study. The areas included in the inventory exhibited similar rainfall indexes, ranging from approx. 1,200 to 1,500 mm/year. The farms adopted no-tillage practices. The watering systems were based on both gravity and drip irrigation, and used both surface water and groundwater.

2.4 Geographical extension and time-frame

The study was developed in the State of São Paulo since it is responsible for the bulk of the oranges produced for the FCOJ processing industries. The State was divided into two orange-growing regions—North and South, characterized by different edaphoclimatic factors and phytosanitary problems, which directly influence not only productivity but also production costs. The average temperature of this region is 16–18°C and the average annual precipitation ranges from 1,000 to 1,400 mm (Instituto Nacional de Pesquisas Espaciais 2004). The regions evaluated in this study are located between 47° to 50° W longitude and 22°30′ to 20°5′ S latitude.

Time-related coverage—Data refer to the 2002/2003 crop.

2.5 System boundaries

Only the inputs and outputs related to tillage were considered in this study, as defined by the cradle-to-gate approach, as shown in Fig. 1. The production of fertilizers, soil correctors and pesticides was not included within the

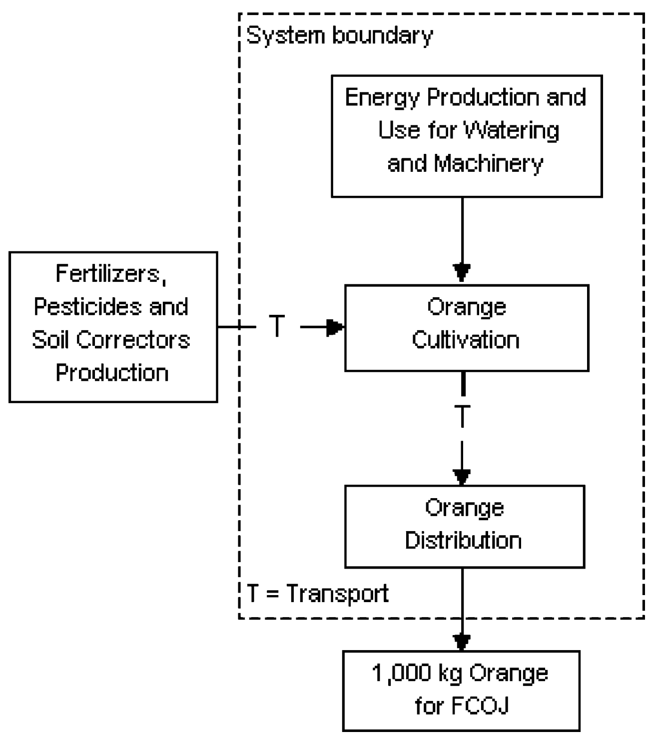

Fig. 1 System boundaries considered in this study

boundaries of the study—only their amounts and their transportation to the farms. The production of energy directly used in the agricultural operations to operate farm machinery and watering systems and also in the transportation steps was taken into account. The transport distances for the raw materials, fertilizers, soil correctors, pesticides and orange from the farms to the processing industries were included within the boundaries of the study.

2.6 Data collection and quality

All the information and data considered and evaluated in this study, such as the use of water, energy, fertilizers, pesticides and soil correctors were gathered through in-depth questionnaires either filled in directly by the farm manager or completed by the farm manager and sent in by mail, and included the inputs of water, energy, fertilizers, pesticides and soil correctors, transport and emissions to water, air and soil. The data reflect the cultivation profile of 30 orange farms grouped in 23 questionnaires.

Models developed at CETEA for expressing road transportation and electric power production in Brazil in terms of LCA were adopted (Coltro et al. 2003; Coltro 2008).

CO_2 fixation by orange trees has not been taken into account, but CO_2, K, N, P, Ca, Na, Fe fixation by the fruits were considered according to the methodology described by Mourad et al (2007). This methodology, developed and applied during this study, is simple and can be employed by such different stakeholders as farmers, environment managers and decision-makers as a reference for perennial crop evaluation (Mourad et al. 2007).

2.7 Representativeness

The data refer to a production of 367,200 metric tons (9 million boxes) of oranges, 4 million plants in commercial production and an evaluated area that accounts for 19.5% of total orange production of the State of São Paulo.

3 Results and discussion

The main inputs and outputs of the life cycle inventory for oranges grown in Brazil for the functional unit of 1,000 kg of oranges are shown in Table 2. As can be seen, the results vary greatly across the data, with the greatest variation being observed in the water and soil corrector inputs.

Total energy (1,540 MJ/1,000 kg of oranges) accounts all upstream energy use to deliver energy in, for instance, electricity (from hydroelectric, fossil fuels and nuclear power plants) and fossil fuels. Diesel consumption is due to the fuel burnt by the agricultural machinery and in the transportation steps considered.

A consumption of 1,761 kg water for irrigation per 1,000 kg of oranges was found, evidencing the use of significant amounts of this natural resource. Since water is a natural resource that is expected to become increasingly scarce in the future, such high level of consumption should be evaluated properly.

The cultivation of oranges requires the use of fertilizers as sources of macronutrients like N, P and K and micronutrients, such as S, Mn, B, Mb and Zn. These elements are mainly supplied to the soil in the form of inorganic salts, such as urea, phosphates, boric acid, KCl, KNO_3, $MnSO_4$, $ZnSO_4$, ZnO, etc. As shown in Table 2, the total mass of fertilizers (active ingredients and fillers) applied to the crop is approx. 3 times higher than the mass of the active elements actually required.

Acaricides followed by herbicides are the main classes of pesticides used in orange-growing. All the inventoried pesticides are approved by Fundecitrus for the growing of oranges, both as regards type and quantity.

The total mass of soil correction products used to produce 1,000 kg of oranges was approx. 40 kg. Limestone is the most commonly used source of Ca and Mg. These elements are employed for correcting soil acidity.

The “surplus indexes” shown in Table 2 indicate that the maximum value of each input ranges from 2 to 60 times the average values. Although the use of water for irrigation, fertilizers and pesticides depends on the specific needs of each agricultural unit, these great differences evidence a clear opportunity for reduction of these inputs.

The pesticides and fertilizers used in the present study are similar to those described by Sanjuán et al. (2005) in their LCA study for integrated orange production (Sanjuán et al. 2005). The differences observed in terms of type and amount of these inputs probably are related to the geographical characteristics and production aspects of the studied orange regions since the above-mentioned study evaluated the production of oranges in Spain.

3.1 Consumption of pesticides, fertilizers and soil correctors

The input of pesticides in the life cycle inventory of oranges for juice grown in Brazil for the functional unit of 1,000 kg of oranges is depicted in Fig. 2. The straight line in the figure represents the weighted average for this input. The results showed great variation among the farms evaluated. It was observed that the farms in the Northern Region exhibited the largest consumption of pesticides per ton of oranges. The category “Pesticides” includes active compounds known as acaricides, fungicides, herbicides and insecticides as differentiated in Fig. 2, with acaricides being the major pesticide class used in 95% of the farms. The cultivation of oranges in the Northern region requires

Table 2 Summary of the Brazilian life cycle inventory for 1,000 kg of oranges produced during the reference crop year 2002/03

Parameters	Unit	Weighted Average	Minimum	Maximum	SD	Surplus index
INPUT						
ENERGY						
Total energy	MJ	1,540	117	4,419	879	3
Electric (public grid)	MJ	744	0.088	2,663	553	4
RESOURCES						
Diesel	kg	4.19	0.34	36.33	8.90	9
Water						
Total	kg	2,584	81.7	55,485	12,449	22
For disinfection	kg	831	81.7	2,117	628	3
Irrigation	kg	1,761	1,131	54,565	12,369	31
Fertilizers						
Total (Active ingredients and Fillers)	kg	28.56	0.31	64.83	15.12	2
(N, P, K)	kg	11.75	0.079	27.71	6.53	2
(S, Zn)	kg	0.118	0.101	3.91	0.98	33
Pesticides						
Total (Active ingredients and Fillers)	kg	2.75	0.07	13.48	3.24	5
Bactericide	kg	0.017	0.0014	0.54	0.15	32
Acaricide	kg	1.12	0.053	3.19	0.74	3
Fungicide	kg	0.049	0.008	2.81	0.58	58
Herbicide	kg	0.149	0.025	0.363	0.106	2
Insecticide	kg	0.0093	0.00028	0.488	0.114	53
Soil correctors						
Total (Active ingredients and Fillers)	kg	40.45	8.17	649	136	16
(Ca, Mg)	kg	17.75	4.59	284	60	16
LAND USE						
Land use	ha.a	0.0015	0.00092	0.0035	0.0006	2

SD = standard deviation

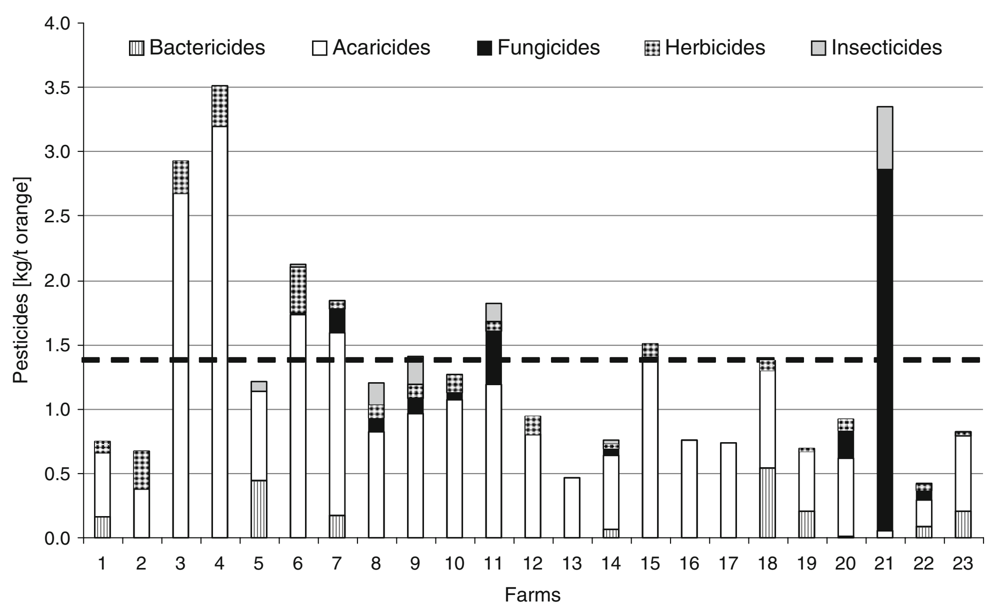

Fig. 2 Consumption of pesticides (only active ingredients) for each farm evaluated for the reference crop year 2002/03. Regions where the farms are located: the Northern São Paulo state area (1 to 13) and the Southern São Paulo State area (14 to 23). Straight line represents the weighted average

more effective phytosanitary control measures due to the high soil water deficit and continuous exposure of the plants to diseases like CVC and citrus canker (Guilardi et al. 2002), both of which are factors that explain the comparatively much higher consumption of pesticides in this region, i.e., 75% of the farms that consumed more pesticides than the weighted average are located in the Northern region.

The current stage of the technology available for growing oranges in tropical regions is intensive in the use of pesticides applied to control and prevent the spreading of diseases. Although pesticides are applied in smaller amounts compared to fertilizers and soil correctors, their degree of environmental persistence is much higher. Copper, usually used as a fungicide, is one of the emissions that contribute most to toxicity, according to Sanjuán et al (2005). However, its toxic effect considerably decreases depending on the soil characteristics of the farm.

The input of fertilizers per ton of oranges (Fig. 3), expressed as the total sum of nitrogen, phosphorus and potassium added to the crop per functional unit supplied by several organic and inorganic sources (only active ingredients) was also largest in the Northern region, a traditional orange-producing area. While in the Southern region only 30% of the farms consumed fertilizers in amounts greater than the weighted average, the opposite was observed in the Northern region, i.e., only 38% of the farms applied fertilizers in quantities lower than the average. One possible explanation would be the scarcity of these nutrients in the soil due to the long periods of time these soils have been continuously used to produce oranges. Furthermore, some of these farms cover extensive planted areas that slope downward, demanding greater amounts of this input due to natural losses during rainy periods.

Traditional extensive orange farming requires significant amounts of fertilizers and soil correction products. The salts added to the soil derive from natural resources, such as rocks and ores from mining processes that are very intensive in energy use. Nonetheless, the stage of fertilizers and soil correctors production fell beyond the boundaries of this study since this is a first tentative expression for a broad number of orange growers in terms of LCI. The inclusion of these inputs in the system boundaries will mainly contribute to acidification, resource depletion and climate change due to the mining processes (Sanjuán et al. 2005).

The salts added to the crop as fertilizers and soil correctors are sources of phosphates, nitrates and sulfates that are carried away by the rainwater to rivers and/or groundwater flows. The regions evaluated include areas in the State of São Paulo with rainfall indexes ranging from approx. 1,000 to 1,400 mm/year (Instituo Nacional de Pesquisas Espaciais 2004). Such high amounts of rainwater are typical for tropical regions and increase the eutrophication potential of Brazilian rivers.

On the other hand, soil acidity seems to be highest on the farms in the Southern region since the amount of soil correctors per ton of oranges produced required higher inputs of these products compared to the values for these items observed in the Northern region (Fig. 4), i.e., whereas approx. 50% of the farms located in the Northern region exhibited a soil corrector input equal to or higher than the weighted average, 80% of the farms in the Southern region shared the same profile with regard to this variable. Besides, farm 18 probably applied excessive amounts of soil corrector and needs to have its soil analyzed again to determine the appropriate amount of this input.

Continuous agricultural cultivation in the same area for many years causes progressive and significant mineralization of the soil. The impact caused by the addition of these salts to the soil is sometimes overlooked and rarely discussed. But it certainly alters the original soil fauna and microorganisms that are essential in the processes of soil formation and maintenance of soil fertility. Furthermore, the use of agricultural machinery increases the erosion potential of the soil.

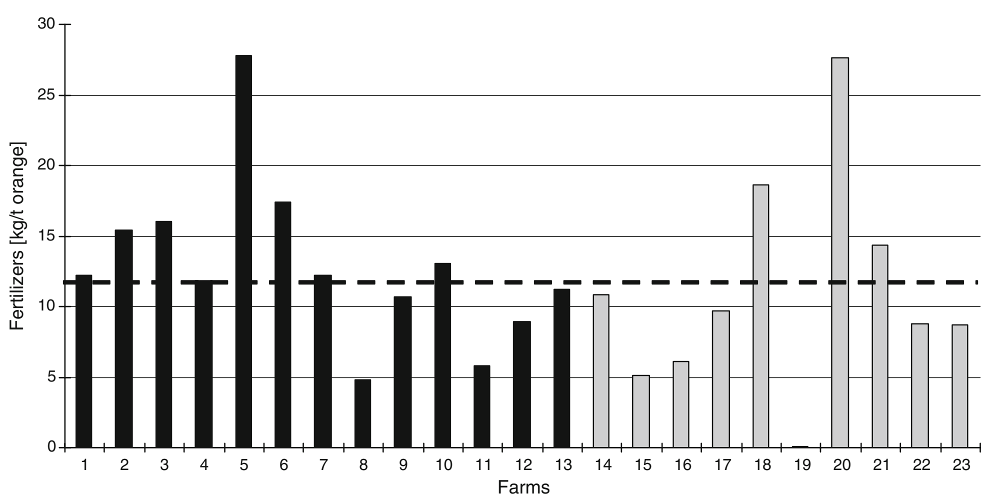

Fig. 3 Consumption of fertilizers (only active components: N, P, K, S and Zn) for each farm evaluated for the reference crop year 2002/03. Regions where the farms are located: the Northern São Paulo state area (1 to 13) and the Southern São Paulo State area (14 to 23). Straight line represents the weighted average

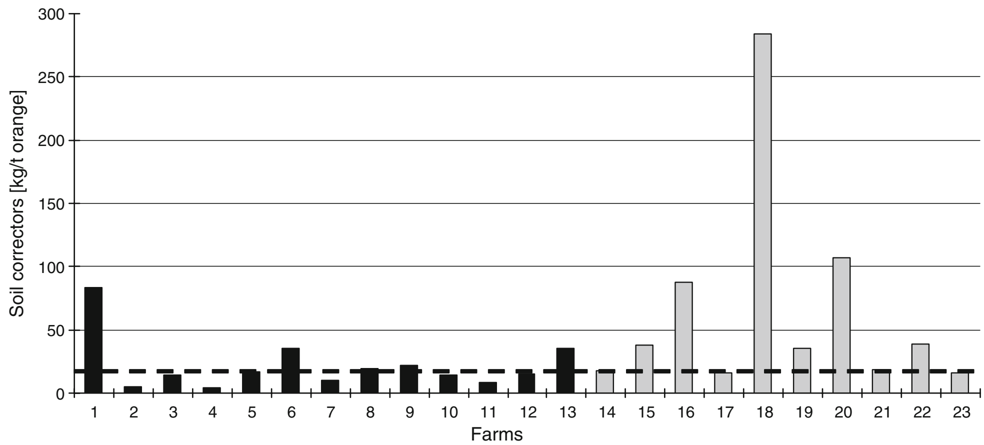

Fig. 4 Consumption of soil correction products (only active compounds: Ca and Mg) for each farm evaluated for the reference crop year 2002/03. Regions where the farms are located: the Northern São Paulo state area (1 to 13) and the Southern São Paulo State area (14 to 23). Straight line represents the weighted average

Although Brazil is the 5th largest country in the world and although land use is not a key issue as it is in smaller countries, the orange-growing regions are located in the State of São Paulo, a part of the country with high demographic density. Aside from this, the transformation of land as a result of cultivation should be considered, since a significant portion of the population lives close to the planted areas and is subjected to the environmental impacts associated with fertilizers and agrochemicals.

3.2 Environmental profile of orange growers

Taking into account some of the inputs previously discussed and comparing each farm with the weighted average of these inputs, it was observed that:

- 61% of the farms evaluated consumed lower amounts of pesticides than the average obtained for this input;
- 57% of the farms evaluated were found to consume fertilizers in amounts below the average;
- 43% of the farms evaluated consumed soil correcting products in quantities lower than the average;
- 30% of the farms evaluated exhibited land use below the average.

Of all the samples evaluated, farm 8 (4% of the sample) exhibited the best environmental profile since the amounts used of these four inputs were equal to or lower than the weighted averages. Besides this orange plantation, the pesticide, fertilizer and soil corrector consumption in the farms of 12, 14, 17 and 23 (17% of the farms) were lower than the average values, but land use was higher. Thus, considering the aspects evaluated in this study, only 21% of the orange growers performed well.

4 Conclusions

One of the study's main goals was to measure the current environmental profile of orange groves in order to establish a scientific basis for evaluating the environmental performance of Brazilian FCOJ in order to help start the discussion on parameters for a future environmental label program.

Considering the aspects evaluated in this study, only 21% of the orange growers showed a good performance, i.e., consumption of pesticides, fertilizers and soil correctors in quantities equal to or lower than the weighted averages, except for the land use on 80% of these farms which was higher than the weighted average.

Although the inputs are directly related to the specific characteristics of each farm and the climatic conditions of its location, this study has identified some farms that could probably reduce the amount of some inputs and improve their environmental performance.

The authors suggest that the average calculated for the five best-performing farms are set as the maximum allowable level and point of departure for the discussion aimed at improving the overall environmental profile of Brazilian FCOJ. To that purpose, the following values are suggested as the lower threshold to start up the above-mentioned process of improvement:

Average	Pesticides (kg/t)	Fertilizers (kg/t)	Soil Correctors (kg/t)	Land use (ha/t)
Northern region	2.5	28.9	30.1	0.03
Southern region	2.0	26.0	119.6	0.04
5 best-performing farms	1.3	28.0	34.4	0.03

In addition to the total levels of these inputs, good agricultural practices should also be considered to enhance the sustainability of Brazilian FCOJ production.

This study provided important results that allow for a better understanding of the agricultural practices and the potential environmental impacts of this product.

5 Recommendations and perspectives

This LCI of orange production in Brazil was only a first attempt to express this cultivation practice in terms of LCI, which is the reason why some important data were not included (e.g., production of fertilizers). The authors focused on gathering a broad set of field data from the two most important orange-growing regions in the State of São Paulo (Northern and Southern regions) in order to model the production of oranges in Brazil. This LCI constitutes an attempt to model the growing of oranges and their transportation to the processing industries.

Some differences in input levels were observed across the farms evaluated, including between those located in the same production region. For that reason, the authors propose that the average values of the five best-performing farms would be set as the starting point for a discussion on a future environmental label for this product since the local edaphoclimatic conditions require that specific sanitary measures should be taken to better protect the groves.

This study identified farms that used excessive amounts of certain inputs in comparison to the regional average. In such cases, a revision of their management plan will help them to enhance both their environmental profile and their economical performance, in addition to change their practices in line with the sustainability principle.

The next step is to include data relative to the production of fertilizers (to be drawn from internationally recognized databases) and discuss the LCA for FCOJ.

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